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(54) **OPTICAL AUTOMATIC ATTITUDE MEASUREMENT FOR LIGHTWEIGHT PORTABLE OPTICAL SYSTEMS**

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G01B 11/26	(2006.01)
G01C 9/00	(2006.01)

(52) **U.S. Cl.**
CPC . ***G01B 11/26*** (2013.01); ***G01C 9/00*** (2013.01)

(58) **Field of Classification Search**
CPC G01B 11/26
USPC 348/135
IPC G01B 11/26
See application file for complete search history.

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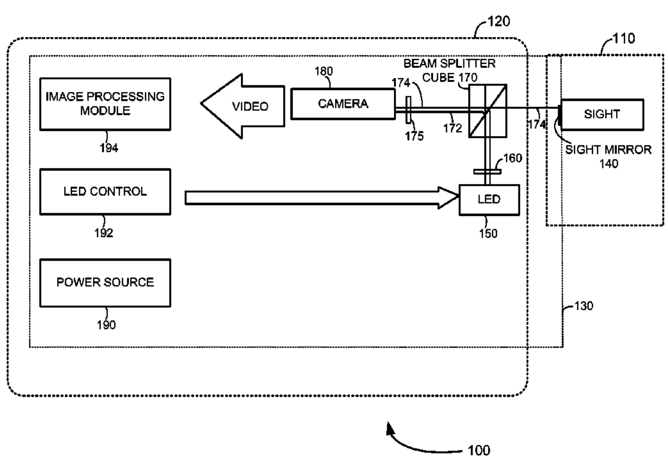
(57) **ABSTRACT**

An optical automatic attitude measurement device for a lightweight portable optical system is disclosed. In one embodiment, a first optical device is configured to provide an attitude beam. A second optical device mechanically coupled to the first optical device to a lose tolerance. The second optical device is configured to provide a reference beam and to receive the attitude beam from the first optical device. The second optical device is further configured to obtain an attitude measurement by computing a differential measurement between the reference beam and the attitude beam in x and y planes at room temperature.

12 Claims, 6 Drawing Sheets



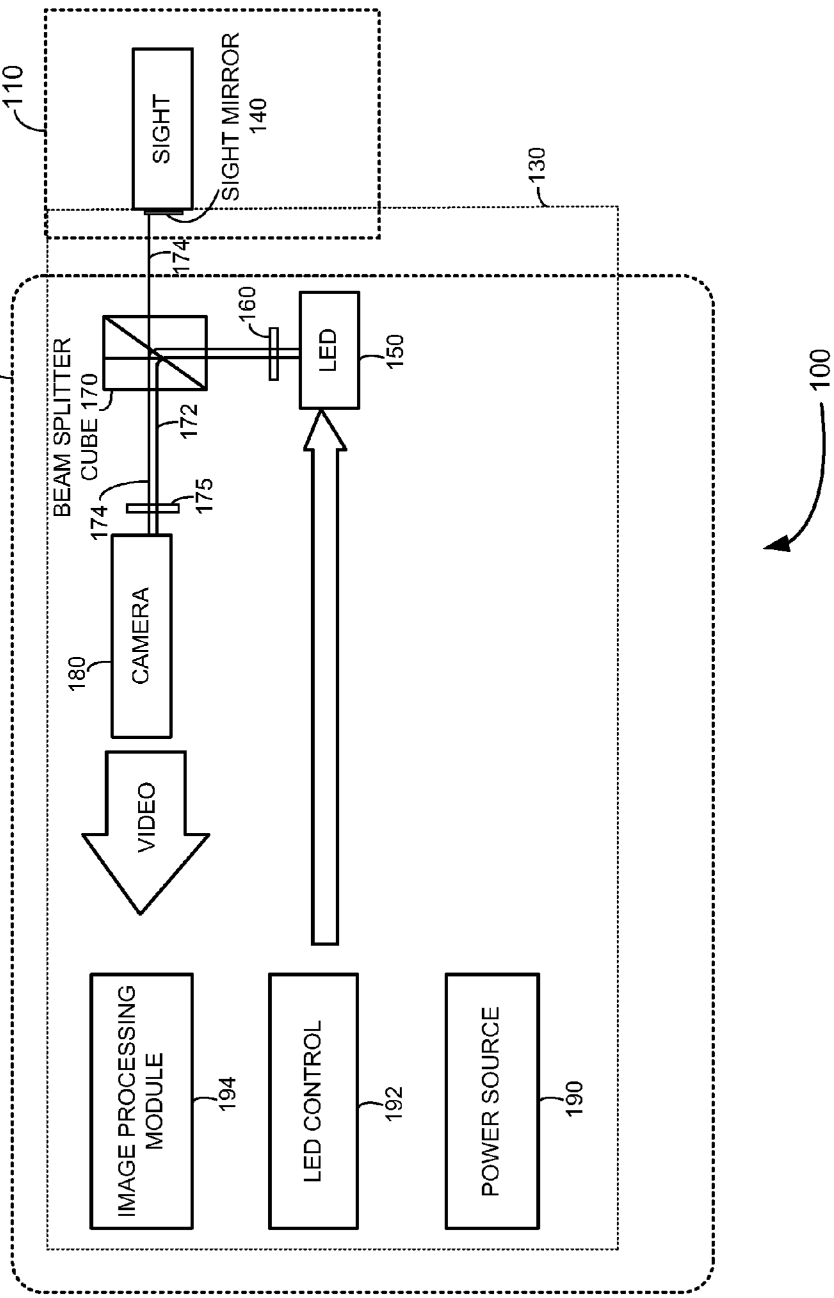

110
SIGHT
SIGHT MIRROR
140
130
174
120
BEAM SPLITTER
CUBE 170
160
LED
150
172
174
175
CAMERA
180
VIDEO
100
IMAGE PROCESSING
MODULE
194
LED CONTROL
192
POWER SOURCE
190

FIG. 1

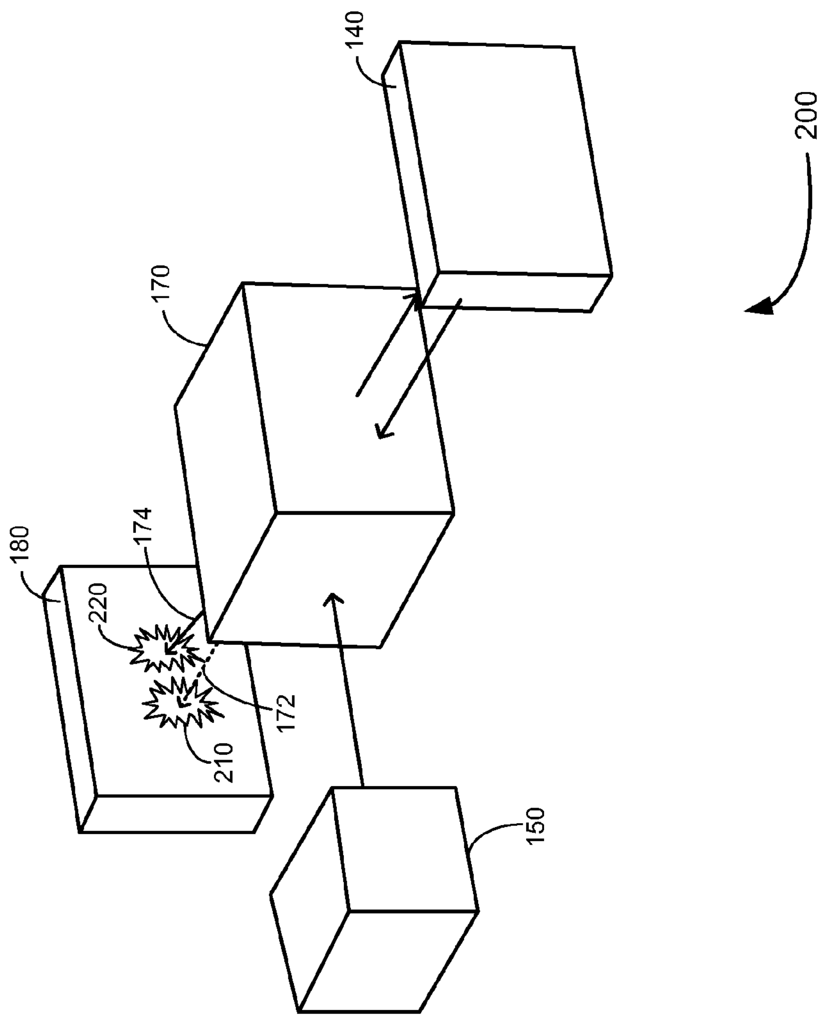


FIG. 2

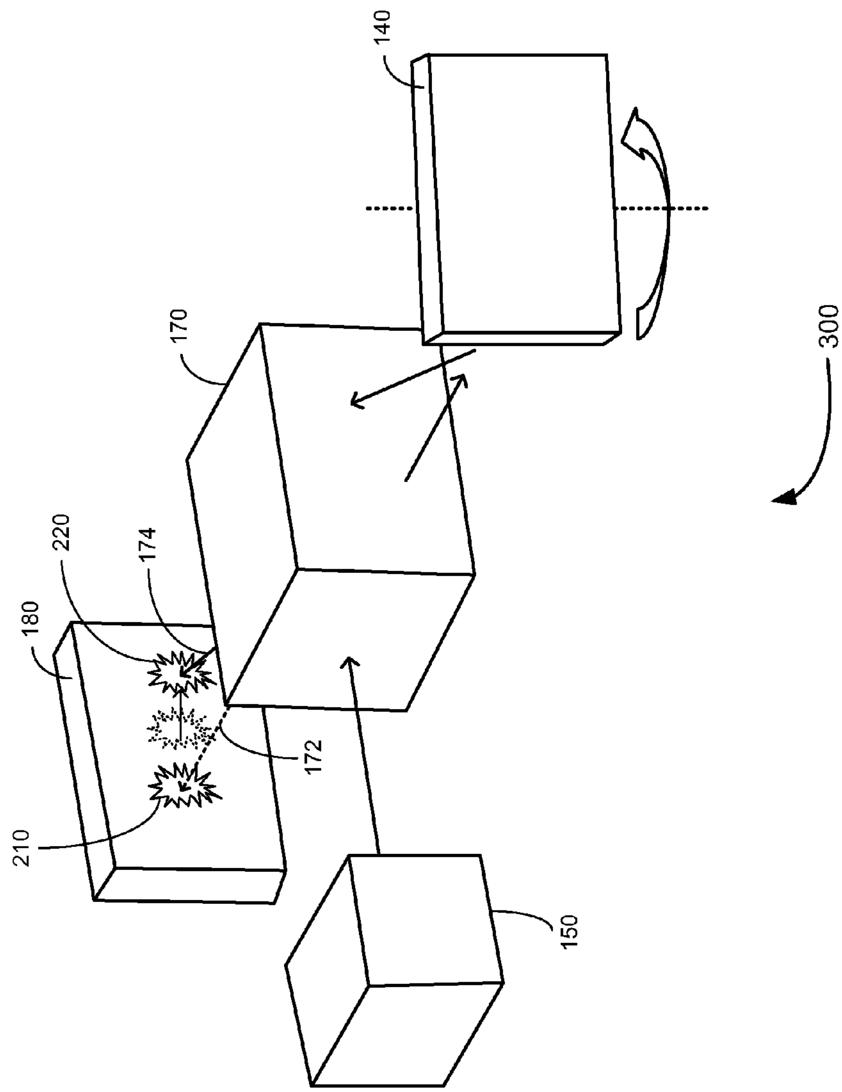


FIG. 3

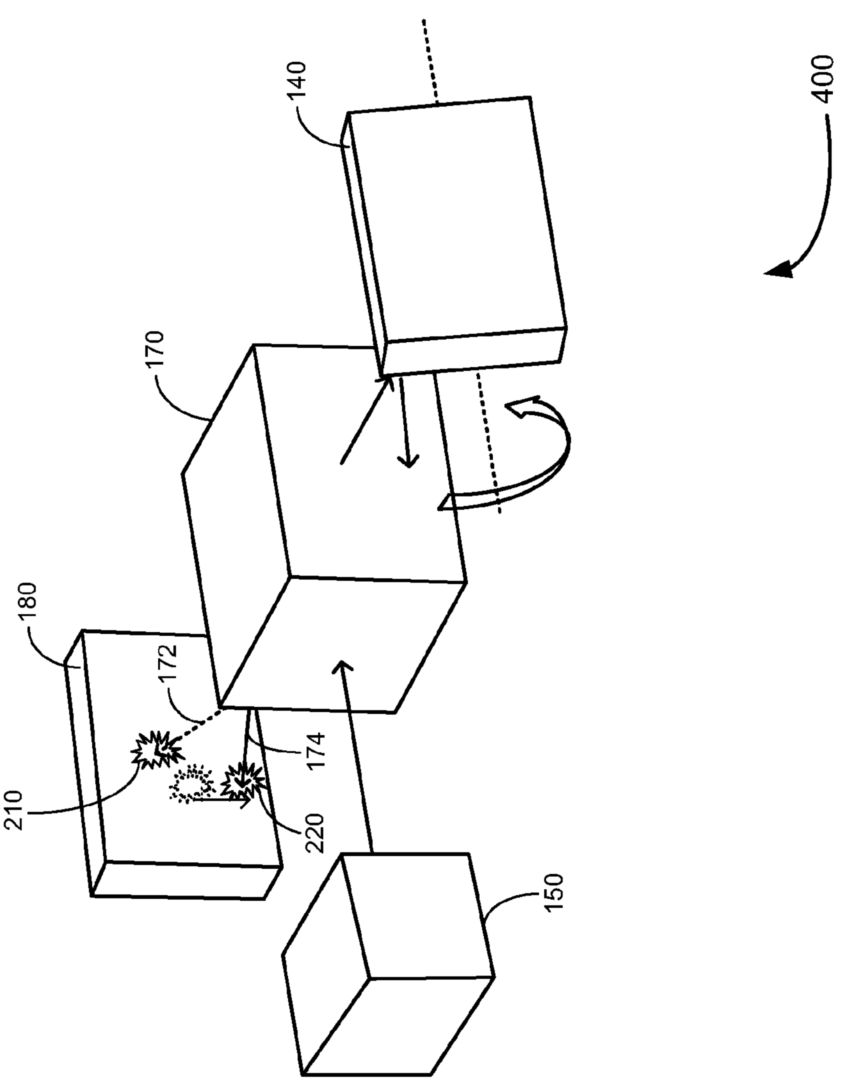


FIG. 4

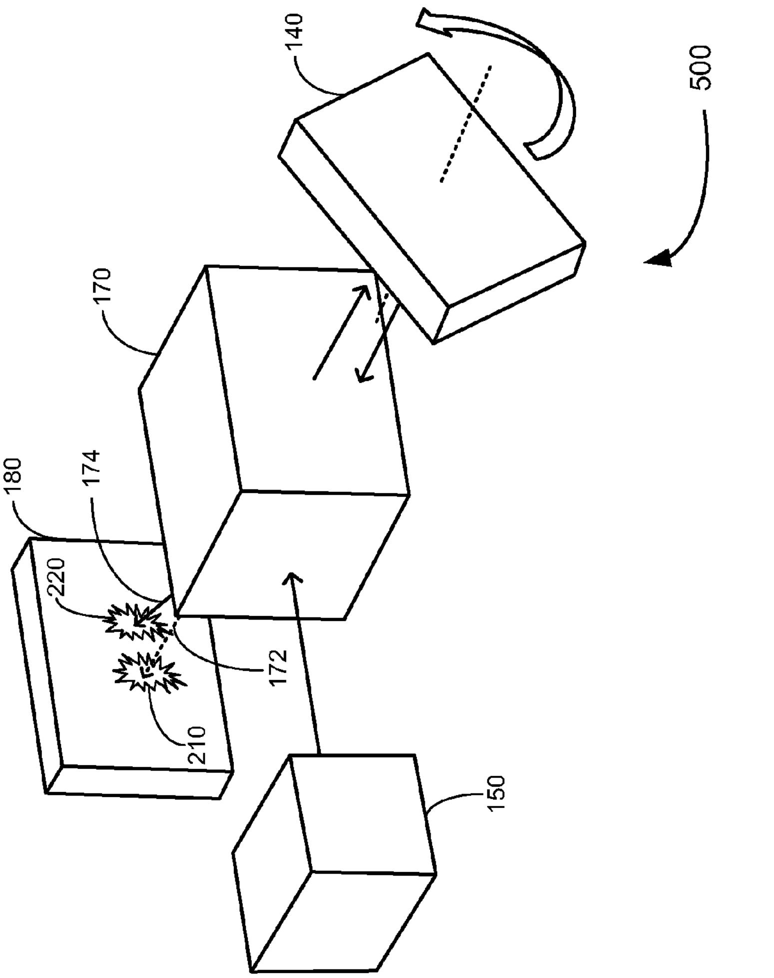


FIG. 5

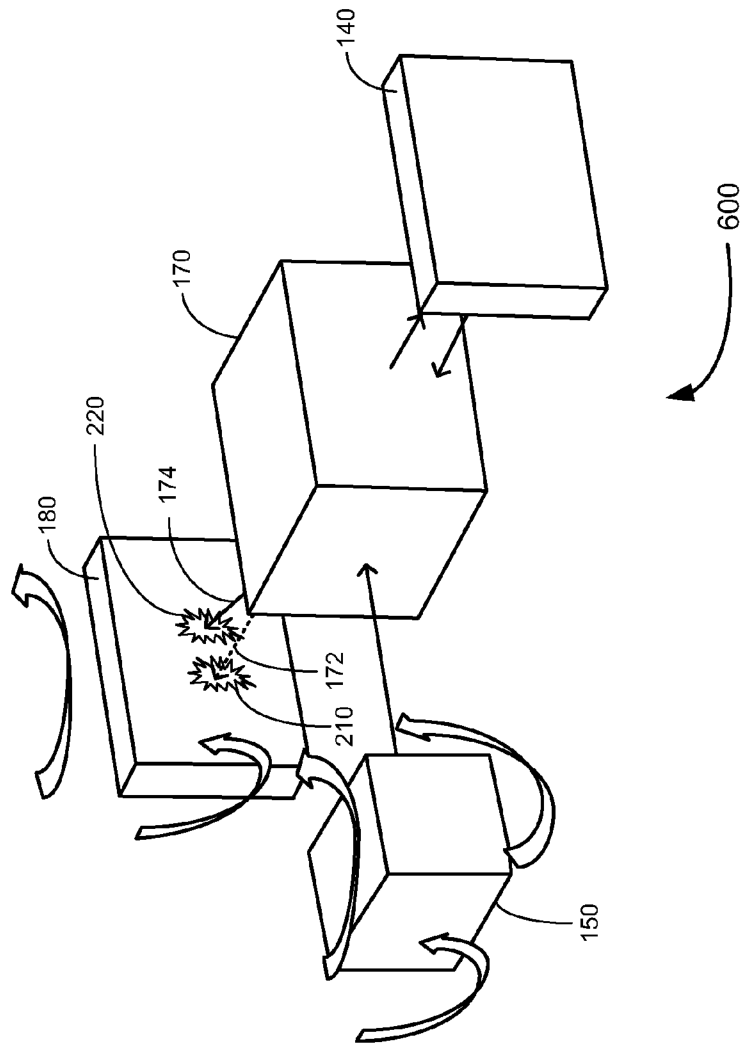


FIG. 6

OPTICAL AUTOMATIC ATTITUDE MEASUREMENT FOR LIGHTWEIGHT PORTABLE OPTICAL SYSTEMS

CROSS-REFERENCE TO RELATED APPLICATIONS

This Application claims rights under 35 USC §119(e) from U.S. Application 61/660,117 filed Jun. 15, 2012, the contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to optical systems and more particularly to attitude adjustment for light weight portable optical systems.

2. Brief Description of Related Art

Existing systems measure all three axes of rotation, i.e., angular attitudes, such as pitch, roll and yaw to measure attitude between optical devices. This can be very expensive and calibration intensive and may drive down reliability. Further, attitude between two optical devices, such as between a laser targeting system and a receiver, for example, a north finder is critical to reduce error in target computations. Typically, very large and heavy mechanical interfaces (couplings) are used between the optical devices to hold the two devices tightly and to ensure good alignment from tolerance perspective. However, such large mechanical interfaces may be sensitive, and if they get fouled, dirty, and/or banged, may result in misalignment and unexpected errors.

Another existing approach to measure attitude is to use a checker board pattern to generate parallel lines that provide depth information (pitch, yaw and roll) as the lines diverge or converge in the image captured by the camera. To obtain a higher precision in 3 dimensional attitude measurement between the optical devices, such an approach requires calibration on the non-linear aspects of the camera lens over temperature which may significantly increase cost. Also, these alternative methods require the measurement of roughly 40 or so reference angles and over a range of roughly six temperature set points.

SUMMARY OF THE INVENTION

An optical automatic attitude measurement device and method for lightweight portable optical systems is disclosed. According to one aspect of the present subject matter, the optical automatic attitude measurement device includes a first optical device is configured to provide an attitude beam. A second optical device mechanically coupled to the first optical device to a lose tolerance. The second optical device is configured to provide a reference beam and to receive the attitude beam from the first optical device. The second optical device is further configured to obtain an attitude measurement by computing a differential measurement between the reference beam and the attitude beam in x and y planes at room temperature.

BRIEF DESCRIPTION OF THE DRAWINGS

The advantages and features of the present disclosure will become better understood with reference to the following detailed description and claims taken in conjunction with the accompanying drawings, wherein like elements are identified with like symbols, and in which:

FIG. **1** illustrates an example optical automatic attitude measurement device for lightweight portable optical systems, according to an embodiment of the present subject matter;

FIG. **2** illustrates travel paths of two collimated light beams coming from an LED to a beam splitter, to a sight mirror and then to camera, such as those shown in FIG. **1**, which results in a captured image including two dots associated with two collimated beams, according to an embodiment of the present subject matter; and

FIG. **3** illustrates effects of yaw movement between the two optical devices, such as those shown in FIG. **1**, on a captured image including two dots, which results in an "X" movement on one of the dots, according to an embodiment of the present subject matter.

FIG. **4** illustrates effects of pitch movement between the two optical devices, such as those shown in FIG. **1**, on a captured image including two dots, which results in a "Y" movement on one of the dots, according to an embodiment of the present subject matter.

FIG. **5** illustrates effects of roll between the two optical devices, such as those shown in FIG. **1**, on a captured image including two dots, which results in no movement in the two dots, according to an embodiment of the present subject matter.

FIG. **6** illustrates effects of roll between LED and camera, such as those shown in FIG. **1**, on a captured image including two dots, which results in both the beams and the 2 dots moving together, according to an embodiment of the present subject matter.

DETAILED DESCRIPTION OF THE INVENTION

The exemplary embodiments described herein in detail for illustrative purposes are subject to many variations in structure and design.

The terms "beam" and "light beam" are used interchangeably throughout the document.

FIG. **1** illustrates an example optical automatic attitude measurement device **110** for lightweight portable optical systems **100**, according to an embodiment of the present subject matter. As shown in FIG. **1**, the optical automatic attitude measurement system **100** includes a first optical device **110** and a second optical device **120** that are mechanically coupled to a loser tolerance than what is required for an optical attitude measurement system that solely depends on mechanical coupling to obtain a desired 3 dimensional attitude between the optical devices. Also, as shown in FIG. **1**, the first optical device **110** and the second optical device **120** includes an automatic attitude measurement device **130**. Further as shown in FIG. **1**, the first optical device **110** includes a sight mirror **140** of the automatic attitude measurement device **130**. Furthermore as shown in FIG. **1**, the second optical device **120** includes a light source **150**, a first collimating optic device **160**, a beam splitter cube **170**, a second collimating optic device **175** and a camera **180** of the automatic attitude measurement device **130**. Further, as shown in FIG. **1**, the automatic attitude measurement device **130** includes a power source **190**, an LED control **192** and an image processing module **194**.

In operation, the first optical device **110** provides an attitude beam **174**. Further in operation, the second optical device **120** provides a reference beam **172** and also receives the attitude beam **174** from the first optical device **110**. The second optical device then obtains an attitude measurement by computing a differential measurement between the reference beam **172** and the received attitude beam **174** in x and y planes. The attitude measurement is done at room temperature. Further, the obtained attitude measure is impervious to ambient conditions, such as temperature, shock, vibration and the like. Exemplary first optical device **110** and second optical device **120** are first targeting system and a second targeting system, first targeting system and a receiver, such as north finder and so on.

The light source **150** emits a light beam. Exemplary light source is a light emitting diode (LED). The power source **190** provides the needed power to the LED to generate the beam. The beam then passes through the first light collimating optic device **160**. The beam splitter cube **170** is then configured to receive the collimated beam from the light source **150** via the first light collimating optic device **160**.

Upon receiving the collimated beam from the first collimating optic device **160**, the beam splitter cube **170** splits the collimated beam into the reference beam **172** and the attitude beam **174**. The beam splitter cube **170** is configured so that the reference beam **172** goes through the beam splitter cube **170** and reflects back as shown in FIG. **1**. The beam splitter cube **170** is also configured to reflect the attitude beam **174** and direct the reflected attitude beam **174** towards the sight mirror **140** residing in the first optical device **110** as shown in FIG. **1**.

Upon receiving the reflected attitude beam **174** from the beam splitter cube **170**, the sight mirror **140** reflects the attitude beam **174** back to the beam splitter cube **170** as shown in FIG. **1**. The beam splitter cube **170** then passes the received reflected attitude beam **174**, from the sight mirror **140**, through the beam splitter cube **170** and directs the reflected attitude beam **174** along with the reflected back reference beam **172** towards the camera **180** and illuminates the camera **180** to generate two associated dots **210** and **220** on a captured image as shown in FIGS. **1** and **2**. Exemplary camera is a cell phone type camera.

In some embodiments, the image processing module **194** computes pixel distance between the two dots **210** and **220**, formed on the captured image by the camera **180**, in both x and y planes and evaluates 2 of 3 angle attitudes between the first optical device **110** and the second optical device **120**. The three angle attitudes are pitch, roll and yaw. In these embodiments, the reference beam **172** and the attitude beam **174** are configured to produce the two dots, on the captured image, having a predetermined size that is suitable for the image processing module to evaluate the centers of the two dots **210** and **220** to single pixel accuracy. Further in these embodiments, the image processing device **194** uses well known centroiding algorithms to evaluate the centers of the two dots **210** and **220**. With the optical device arrangement shown in FIG. **1**, the movement of the camera **180** and the LED **150** with respect to the beam splitter cube **170** and the sight mirror **140** does not result in any displacement change between the two dots **210** and **220**.

Based on the orientation of the sight mirror **140** residing in the first optical device **110** and the beam splitter cube **170** and the camera **180** residing in the second optical device **120**, the automatic attitude measurement device **130** measures 2 of the 3 angle attitudes. For example, as shown in FIG. **3**, if the sight mirror **140** is rotated about its vertical axis and the beam splitter cube **170** is rotated within the plane of a paper, then the attitude manifests itself into an x-movement about the center of the two dots **210** and **220**. Similarly, as shown in FIG. **4**, if the sight mirror **140** is rotated about its horizontal axis and the beam splitter cube **170** is rotated within the plane of the paper, then the attitude manifests itself into a y-movement about the center of the two dots **210** and **220**. Further as shown in FIG. **5**, if the sight mirror **140** is rotated about its central axis and the beam splitter cube **170** is rotated within the plane of the paper, then the sight mirror **140** rotation does not manifest itself in any attitude change between the first optical device **110** and the second optical device **120**. Furthermore as shown in FIG. **6**, any movement in the light source **150** and the camera **180** results in both the reference beam and the attitude beam moving together by a same amount resulting in no attitude manifestation.

In some embodiment, the second collimating optical device **175** is configured to further collimate the reflected reference beam **172** and the attitude beam **174**.

The above technique is applicable to any two optical devices that require computing where they are pointing to. The above technique reduces weight and significantly improves tolerance to fouling in battlefield. Further, the above technique provides environmentally sensitive interface while maintaining high accuracy between optical devices in a portable optical system. Furthermore, the above technique is an active feedback system that dynamically provides the needed attitude measurement while the optical system is in operation. Moreover, the above technique significantly loosens up tolerance requirements to be maintained between the optical devices in the portable optical system. In addition, the above system can be deployed in confined volumes. Also, the present invention uses off-the-shelf LED and cell phone type cameras, thereby component costs are significantly reduced. The above technique is also impervious to environmental conditions and whereas the alternate methods require calibrating out the environmental impacts, such as temperature and so on. The above technique is based on differential measurement and all of the components, which can move with environmental impacts, affect both the reference and measurement beams, thereby the final attitude measurement between the two optical devices are differential in nature resulting in being impervious to the environmental conditions.

The foregoing descriptions of specific embodiments of the present disclosure have been presented for purposes of illustration and description. They are not intended to be exhaustive or to limit the present disclosure to the precise forms disclosed, and obviously many modifications and variations are possible in light of the above teaching. The embodiments were chosen and described in order to best explain the principles of the present disclosure and its practical application, to thereby enable others skilled in the art to best utilize the present disclosure and various embodiments with various modifications as are suited to the particular use contemplated. It is understood that various omission and substitutions of equivalents are contemplated as circumstance may suggest or render expedient, but such are intended to cover the application or implementation without departing from the spirit or scope of the claims of the present disclosure.

What is claimed is:

1. An optical automatic attitude measurement device for a lightweight portable optical system, comprising:

a first optical device including a sight mirror; and

a second optical device mechanically coupled to the first optical device to a lose tolerance, the second optical device comprises:

a light source to generate a beam;

a first collimating optic device to collimate the generated beam;

a beam splitter cube configured to:

receive the collimated beam from the first collimating optic device and split the collimated beam into a reference beam and an attitude beam;

reflect the attitude beam and direct the reflected attitude beam towards the sight mirror residing in the first optical device; and receive the reflected attitude beam from the sight mirror and pass it through the beam splitter cube, wherein the beam splitter cube is configured such that the reference beam goes through the beam splitter cube and gets reflected back; and

a camera configured to receive the reflected attitude beam and the reflected reference beam from the beam splitter cube, wherein the second optical device is configured to obtain an attitude measurement by computing a differential measurement between the reflected reference beam and the reflected attitude beam from the first optical device in x and y planes at room temperature.

2. The device of claim **1**, wherein the obtained attitude measurement is impervious to ambient conditions, and wherein the ambient conditions are temperature, shock and/or vibration.

3. The device of claim **1**,

wherein the received attitude beam and the reference beam illuminate the camera and generate associated two dots on a captured image.

4. The device of claim **3**, wherein the light source is a light emitting diode (LED).

5. The device of claim **4**, wherein the camera is a cell phone type camera.

6. The device of claim **5**, wherein the second optical device comprises:

a power source for the LED;

a LED control to provide the needed light source for the automatic attitude measurement; and

an image processing module configured to compute pixel distance between the two dots in both x and y planes on the camera and evaluate 2 of 3 angle attitudes between the first optical device and the second optical device.

7. The device of claim **6**, wherein the angle attitudes are selected from the group consisting of pitch, roll, and yaw.

8. The device of claim **3**, wherein the second optical device further comprises a second collimating optical device for further collimating the received reference beam and the attitude beam from the beam splitter cube and before the reference beam and the attitude beam enters the camera.

9. The device of claim **1**, wherein the sight mirror in the first optical device reflects the received attitude beam back to the beam splitter cube.

10. An optical automatic attitude measurement device for a lightweight portable optical system, comprising:

a first optical device including a sight mirror; and

a second optical device mechanically coupled to the first optical device to a lose tolerance, the second optical device comprises:

a light source to generate a beam;

a first collimating optic device to collimate the generated beam;

a beam splitter cube configured to receive the collimated beam from the first collimating optic device and split the collimated beam into a reference beam and an attitude beam, wherein the beam splitter cube is further configured to reflect the attitude beam and direct the reflected attitude beam towards the sight mirror residing in the first optical device, wherein the sight mirror in the first optical device reflects the received attitude beam back to the beam splitter cube, and wherein the beam splitter cube is furthermore configured to receive the reflected attitude beam from the sight mirror and pass it through the beam splitter cube and the beam splitter cube is also configured such that the reference beam goes through the beam splitter cube and gets reflected back;

a camera configured to receive the reflected attitude beam and the reflected reference beam from the beam splitter cube, and wherein the received attitude beam and the reference beam illuminate the camera and generate associated two dots on a captured image; and

an image processing module configured to obtain an attitude measurement by computing pixel distance between the two dots in both x and y planes on the camera and evaluate 2 of 3 angle attitude measurements between the first optical device and the second optical device, wherein the image processing computes centers of the two dots to single pixel accuracy.

11. The device of claim **10**, wherein the two dots are of a predetermined size that is suitable for the image processing module to evaluate centers of the two dots to the single pixel accuracy.

12. The device of claim **10**, wherein the angle attitudes are selected from the group consisting of pitch, roll, and yaw.

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